



**HAL**  
open science

## Study of the global hydrodynamics and gas- liquid transfer in a thin-gap bubble column

Charlène Thobie, W. Blel, Emilie Gadoin, Pattarmadathil Joseph, Jeremy Pruvost, Caroline Gentric

► **To cite this version:**

Charlène Thobie, W. Blel, Emilie Gadoin, Pattarmadathil Joseph, Jeremy Pruvost, et al.. Study of the global hydrodynamics and gas- liquid transfer in a thin-gap bubble column. 13th International Conference on Gas-Liquid and Gas-Liquid-Solid Reactor Engineering (GLS-13), Aug 2017, Bruxelles, Belgium. hal-02344604

**HAL Id: hal-02344604**

**<https://hal.science/hal-02344604v1>**

Submitted on 4 Nov 2019

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Study of the global hydrodynamics and gas-liquid transfer in a thin-gap bubble column

Charlène Thobie<sup>a</sup>, Walid Blel<sup>a</sup>, Emilie Gadoin<sup>b</sup>, Toms Pattarmadathil.Joseph<sup>b</sup>, Jérémy Pruvost<sup>a</sup>, Caroline Gentric<sup>a</sup>

<sup>a</sup> Affiliation, address, phone number, email address of the First Author

<sup>b</sup> Affiliation, address, phone number, email address of the First Author

## Introduction

The cultivation of microalgae in photobioreactors (PBR) is a process that knows a strong infatuation in recent years because of its many fields of application (energy, green chemistry, food supplement, etc.). Use of low optical thickness (few millimeters) photobioreactors allows intensifying the volumetric productivity by increasing the concentration of microalgae. Therefore, the amount of water used decreases. This causes a reduction in production, agitation and harvesting costs [1]. These low thickness reactors are called "high volume productivity photobioreactors". Technologies already exist to meet the objective of high cell concentrations. Among these, the Algofilm technology is based on a falling film of small thickness which flows over a smooth surface, exposed to the solar light [2], [3]. Another technology consists in a vertical photobioreactor of small thicknesses ( $e < 7\text{mm}$ ) [4], operating in a bubble column mode. Bubble columns are indeed commonly used as they allow to circulate the culture and to ensure the gas-liquid transfers necessary for the growth of microorganisms.

The present study focuses on this last type of thin gap bubble column. Hydrodynamics of gas-liquid reactors is known for its complexity: deformability of the bubbles, breaking and coalescence phenomena, existence of various flow regimes that are not easy to predict. It is important to characterize and predict the operating conditions of gas-liquid reactors, because the hydrodynamic behavior and transfer are different from one regime to another. The characterization of hydrodynamics in confined environments has little been dealt in the literature. [5], [6]. Hydrodynamics in a thin-gap bubble column appears as a key element, rendered specific by the strong confinement (interaction of bubbles with the walls), and possible increase the viscosity of the liquid phase due to high cell concentration [4]. Potential problems such as reduced mixing capabilities, poor gas-liquid mass transfer or biofilm development can also appear.

## Objective

The aim of this work is to characterize the global hydrodynamics and gas-liquid mass transfer in an intensified vertical photobioreactor technology of reduced thickness (4 mm). Concerning hydrodynamics, the evolution of the void fraction with the superficial gas velocity is determined, this allows to characterize the different flow regimes; mixing is evaluated from mixing time determination based on tracing experiments. The gas-liquid mass transfer is quantified via  $kLa$  measurements and its evolution with the gas superficial velocity is analyzed. All these experiments are conducted for model fluids of different viscosities, mimicking different cell concentrations of microalgae. The terminal velocity of a single bubble in the confined column is also determined since it allows to explain some characteristics of the global hydrodynamics. All these results are compared to literature results for conventional bubble columns.

## Results and conclusion

The evolution of the global gas hold-up with increasing superficial gas velocity, determined via static pressure measurements, is plotted in Figure 1 for the air-water system. It is compared to values obtained in a more conventional parallelepipedic bubble column of 4 cm thickness [7]. Regime transitions are also put into evidence in this figure. At low superficial gas velocities, the gas hold-up is slightly higher than for classical bubble columns. This can be explained by the terminal velocity in the thin-gap bubble column which is reduced by 30% to 50% compared to conventional bubble columns. So the residence time of the bubbles is higher in the homogeneous regime (before coalescence of bubbles). In fact, due to the significant confinement, the bubbles will undergo more friction. This will have an influence on the residence time of the bubbles in the column and thus on the gas hold-up. Beyond a certain superficial gas velocity, the gas hold-up is lower than that obtained for classical bubble column. This is due to the fact that in the case of this study, the transition and heterogeneous regimes appear at lower superficial velocity ( $U_g$ ) (Figure I).

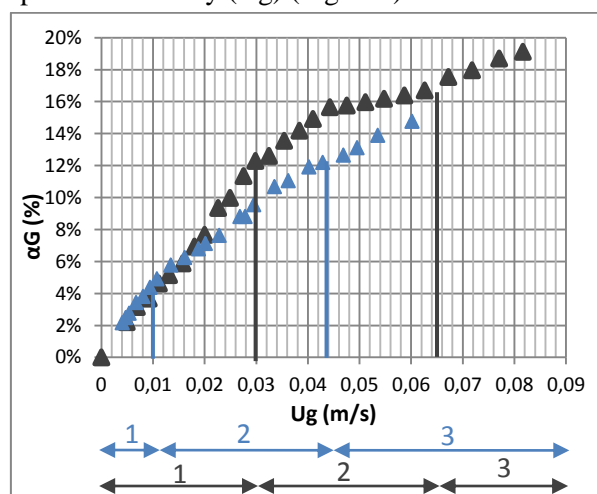


Figure 1 : Comparison between this application ( $\blacktriangle$ ) and the classical rectangular section bubble column used by Olmos [7] ( $\blacktriangle$ ). 1; 2; 3 are respectively homogeneous, transition and heterogeneous regime.

Concerning the gas-liquid mass transfer, from a superficial gas velocity of 0.02 m/s, it is lower than in classical bubble columns. This can be explained by Higbie model that links gas liquid mass transfer ( $kLa$ ) to the exposure time between a liquid element and a gas bubble. In the confined bubble column, the drag coefficient is more important, so terminal velocity of bubbles is lower. Thus, the exposure time is higher and which decreases the gas-liquid mass transfer coefficient.

## Bibliography

- [1] Gross M., Wen Z. « Yearlong evaluation of performance and durability of a pilot-scale Revolving Algal Biofilm (RAB) cultivation system ». *Bioresource Technology*. 2014. Vol. 171, p. 50-58.
- [2] Doucha, J. and Livansky, K.. « Process of outdoor thin-layer cultivation of microalgae and blue-green algae and bioreactor for performing the process ». Patent n° US5981271. 1999.
- [3] Le Borgne F. « Développement d'un photobioréacteur solaire intensifié en vue de la production à grande échelle de biomasse microalgale ». Thèse de Doctorat, Université de Nantes, 2011.
- [4] Souliès A. « Contribution à l'étude hydrodynamique et à la modélisation des photobioréacteurs à haute productivité volumique ». Thèse de Doctorat, Université de Nantes, 2014.
- [5] Roudet M., Billet A.M., Risso F., Roig V. « PIV with volume lighting in a narrow cell: An efficient method to measure large velocity fields of rapidly varying flows ». *Experimental Thermal and Fluid Science*. 2011. Vol. 35, p. 1030-1037.
- [6] Roig V., Roudet M., Risso F., Billet A.M. « Dynamics of a high-Reynolds-number bubble rising within a thin gap ». *Journal of Fluid Mechanics*. 2012. Vol. 707, p. 444-466.
- [7] Olmos E. « Etude expérimentale et numérique des écoulements gaz-liquide en colonne à bulles ». Thèse de Doctorat, Université de Lorraine, 2002.